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Maine Agricultural Experiment Station

ORONO

BULLETIN 248 **MARCH, 1916**

LIFE HISTORIES OF LEAFHOPPERS OF MAINE

ISSUED
MAY 15 1916
Entom-paper 85

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*Died February 23, 1916

†In collaboration with U. S. Department of Agriculture.

BULLETIN 248.

STUDIES OF LIFE HISTORIES OF LEAFHOPPERS OF MAINE.*

HERBERT OSBORN, Consulting Entomologist.

The following report includes the results of studies in Maine during the summer of 1914 and are in the nature of a continuation of the survey of the leafhoppers of the state begun in 1913. As a result of that seasons work a few species considered as of special economic importance were selected for a more exhaustive study and during the season of 1914 when I devoted about ten weeks to the study, observations were made upon the species discussed in this paper.

The leafhoppers and the froghoppers (*Jassidae* and *Cercopidae*) while belonging to distinct families and possessing some very different habits agree in so many details and especially so much in the nature of their work and the injury occasioned to similar crops that they can very properly be treated in connection. Moreover there are a number of general considerations that can very properly be grouped together so that the introduction may be counted as applying to members of both groups.

Except for the notable production of the frothy masses it is probable that agriculturists generally would count them all as one general group of plant sucking hoppers.

The studies of the season have centered especially on the species injurious to grass and grain crops. The work dealing with leafhoppers is presented in this paper and that devoted to froghoppers is in the main reserved for treatment in a separate bulletin soon to be issued by this Experiment Station.

Considering the importance of the hay crop, which in Maine ranks first in the agricultural products of the state, there is

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*Papers from the Maine Agricultural Experiment Station; Entomology No. 85.

abundant reason to study the insect pests that serve to limit the yield and injure the quality of the crop. Statistics for 1913 (U. S. Dept. Agriculture) show 1,194,000 acres devoted to the crop with yield of 1,194,000 tons and value of 16,597,000 dollars. This estimate is lower than that of previous years and does not include pasturage which, from the fact that the state has 259,000 cattle valued at near ten millions of dollars, must represent a considerable factor in the agriculture of the state.

The insect depredations on grass are of such a character as to escape due recognition, partly because of the minuteness of most of the insects concerned and the obscure nature of their attack, partly because the injury consists of a steady drain through the season and seldom results in the total destruction of plants, and partly because the injury and loss if noticed at all is very likely to be charged to other agencies such as weather conditions, exhaustion of soil, "running out" of the meadow, etc.

While demonstration is somewhat difficult there is good reason to believe that a considerable part of the "running out" is due to the multiplication of insect pests in the meadow and that if these could be eliminated the yield would be greatly increased or the period of rotation could be very much extended.

Some rather striking illustrations of the extent of the injury have come to light during the season and may be presented here as a suggestion at least, as to the cause of rapid decrease in yield in fields which in other respects have best of conditions for an average crop.

A very good opportunity to compare the conditions in a field that had been in grass but a short time and one where grass had been growing for a number of years was afforded in a field on the university farm where timothy had been growing for a couple of years and in a near by field, the meadow to the south of the library building, where the grass had been growing for some twelve years. I was told that this latter field had been well manured and had for some years produced good crops but in late years a much lower yield and the appearance of the field would bear out this statement though I did not secure exact figures of yield so as to make a complete comparison.

In the new timothy field, planted in 1912, I counted forty good stems with large heads inside a square foot which would equal 1,000 to twenty-five square feet while in the old field in an equal space there were but 67 good plants.

In the library field the space five feet square gave:

Large healthy stems with full heads	67
Small full formed heads apparently healthy	172
Injured heads small or blasted	673
Undeveloped plants, no heads	1052

The condition of this patch is shown in the photograph the scattering tall plants with fully developed heads showing above the general level while the blighted or undeveloped plants are seen to form a much lower level. Fig. 9a.

The contrast in these plants may also be seen in the height of plants measured and photographed. Fig. 10.

Height of 20 uninjured plants, 3 to 4 feet
Height of injured or blighted plants, 1 to 2 feet
Length of healthy fully developed heads 3 1-2 to 5 1-2 inches
Length of blighted or injured heads 1 to 3 inches

In weight there is also quite a striking contrast as shown in figures from these same samples.

Weight of 20 uninjured plants freshly cut, 100 grms; dry, 62 grms.
Weight of 20 injured plants freshly cut, 30.5 grms; dry, 20 grms.

The weight for the freshly cut samples was taken July 13th and the weights for the dry samples on July 20th.

It may be argued that a larger number of stems or leaves for the defective plants would meet or offset some of this discrepancy in individuals and this is in part true but there must be a great difference in total weight as well.

In order to compare the nutritive value of the injured and uninjured plants a chemical analysis of the samples seemed desirable and this was very kindly undertaken by the Station chemist, Prof. Bartlett. His report is as follows:

Timothy 20 stems stunted plants with blasted heads No. 5532; weight freshly cut, 30.5 gms., dried 20 gms.

Moisture.	Ash.	Nitrogen.	Protein found.	Fiber.	Nitrogen, free extract.	Fat. found.
4.54	3.54	0.78	4.88	26.31	58.83	1.00
Water free	3.71	0.82	5.11	27.56	61.63	1.99

Timothy 20 stems healthy plants with heads in blossom No. 5533; weight freshly cut 100 gms., dried 62 gms.

Moisture.	Ash.	Nitrogen.	Protein found.	Fiber.	Nitrogen, free extract.	Fat.
7.07	4.28	0.83	51.8	33.95	47.29	2.23
Water free	4.61	0.89	5.57	36.53	50.81	2.40

The significant points in this analysis appear to be the greater proportion of protein and fat the most important flesh and fat forming constituents of the hay in the uninjured plants as compared with the injured ones. This bears out what might naturally be expected and what I have long felt must be recognized in the attacks of these pests, that they not only reduce the quantity but lessen the food value of the crop attacked. It would of course be unwarranted to claim that all this difference is due to the insect attack although without very much more precise methods of differentiating the factors concerned in the maturing of the grass crop it will be impossible to measure all the agencies concerned. Nor is it claimed that all this loss is due to leafhoppers as there are other insects present and in this particular field there were considerable numbers of the capsid, *Leptoterna dolobrata* which must have had some influence in the growth of the grass but the dominant forms here were the leafhoppers and froghoppers and I feel confident that these insects must be charged with a large share in the losses that are manifest.

It is very evident that a crop of one or one and a half tons of inferior hay to the acre (an average of one ton to the acre

is shown in the statistics for 1913) where there should be a crop of two and a half to three tons of good hay is a matter of some concern to the grower. Or, if the field is used for pasturage, it is as evident that there is much less of forage for the stock pastured on a given area.

The numbers of the different species may vary from year to year and I am quite sure that the abundance of certain of the species may bear some relation to the length of time during which the field may have been in grass. It appears that the six-spotted leafhopper is one of the first to invade a new field since it produces several generations and is quite migratory in habit. After this, for Maine, the *Deltocephalus minki* appears to be one of the earliest to appear in open fields, later the froghoppers and *Acocephalus striatus* come in abundance and one of the latest, perhaps the least migratory, is the *Acocephalus albifrons* which has been found living down in the ground around the crowns of timothy.

Hibernation in General.

In order to determine the place of hibernation of such of the species as might be present, cages were placed in timothy meadows on Dr. Patch's farm. These cages, two eighteen inches square and two one foot by four feet were set out in early spring before insects had become active and before any migration had been possible. They were crowded down close to the surface of the ground but not below the surface of the soil. While it would be possible for insects of some kinds at least to burrow under the frames there would certainly be no probability that any of the Jassids would, if they were to fly into the field from adjacent fence rows or thickets, do this and it is a fair assumption that species found living within the cages on the grass had hibernated in one stage or another on the spot. The same assumption, while less certain for some other kinds of insects, or for spiders, phalangids, etc., is a fair one especially if the content of the cages agrees well in proportion with the surrounding grassland.

While the primary purpose of these cages was to determine this fact of hibernation in the field, examination showed such an interesting association of animals and one so fairly typical

of the meadow complex that it seemed worth while to make a careful record of the contents of one or two of the cages at least.

Cage 1 was examined and part of the contents secured on July 19th, and part on July 20th, all the actively migrating species being taken on the former day, so that there was no opportunity of loss or gain in the interval. Cage 2 was examined July 20th and in this case from one to two inches of the soil, including practically all loose earth and the roots, as well as all the vegetation in the cage was removed and carefully examined, the insects and other animals sorted and a record kept of number as well as of the species found. This record with identifications as far as carried may be inserted here.

RECORD OF CAGE NUMBER 1.

Acocephalus albifrons L.	113	(50 on 19th, 63 on 20th.)
Acocephalus striatus L.	7	2 adult males, rest nymphs
Deltocephalus configuratus	1	
Deltocephalus sayi, Fitch	4	
Deltocephalus minki, Fieb.	1	
Agallia sanguinolenta Prov.	2	
Phytonomus sp.	1	
Phytonomus punctatus	2	
Elaterid, (Coleoptera)	1	
Crambus (Lepidoptera)	1	
Ants	2	
Spiders	5	

RECORD OF CAGE NUMBER 2.

Acocephalus albifrons L.	108	
Acocephalus striatus L.	13,	10 nymphs, 3 adult males
Deltocephalus sayi Fh.	1	
Athysanus curtisii Fh.	1	
Dicraneura sp.	1	
Agallia sanguinolenta Prov.	4	3 adult, 1 nymph
Agallia 4-punctata Prov.	1	
Philaenus spumarius, L.	3	
Aphids (Nectarophora destructor).	8	
Leptoterna dolobrata (Capsid).	1	
Labops sp. (Capsid).	3	
Agalliastes sp. (Capsid).	2	
Halticus sp. (Capsid).	3	

RECORD OF CAGE NUMBER 2.—Concluded.

Phytonomus sp. (Weevils).	18	4 adult, 7 pupae, 7 larvae
Elaterids	2	
Staphylinidae	1	
Tingid Acalypta ?	1	
Syrphid ? puparium	1	
Ants two sps.	15	1 large black, 14 small red
Spiders two sps.	11	6 adult ? 5 small young ?
Mite (Trombidium sp ?)	1	
Harvestmen (Phalangids)	3	2 adult, 1 small young
Sow bugs (Crustacea)	6	
Snail (Mollusc)	1	

It may be noted that cage 1 would doubtless have shown more of certain kinds if the soil had been thoroughly sifted and also that the small number of the commoner Jassids may be attributed to the presence of the spiders and phalangids which had evidently been making a good living inside the cage. The most noteworthy point probably is the enormous number of *Acocephalus albifrons* which were around the crowns of the grass and even down under the litter and in some cases under loose earth, leading an almost subterranean life.

A cage in another field included capsids, *Leptoterna dolobrata, Philaenus spumarius, Draeculacephala mollipes, Cicadula 6-notata, Acocephalus striatus, Deltocephalus minki* and *sayi, Agallia 4-punctata* and a species of *Dicraneura* aside from other forms not of special importance in this connection.

THE SIX-SPOTTED LEAFHOPPER.

(*Cicadula sexnotata* Fallen.)

This species presents some very interesting questions and, in connection with its very evident ability to cause serious injuries to various crops, merits a careful study.

It is a very widely distributed species occurring in Europe and North America in the latter being known from Alaska to Florida and a number of records of its destructive habits have been given but it has received rather scant attention on the part of economic entomologists. While the insect may be found in numbers the attacks made by the larval stages are often so obscure that they may be overlooked or attributed to other causes.

In referring to the species in my report to the department of agriculture in 1912 I called attention to the rather remarkable fact that while the species is so generally distributed and abundant throughout the United States there was no published record of its occurrence in this country prior to 1884, a fact that very naturally suggests that it might be an introduced species. This supposition is somewhat strengthened by the fact that it is so common to the cultivated cereals. As stated in the article.

"Unfortunately we can not safely assume that lack of record by earlier entomologists is in this case any positive proof that the species was not present. While Say, Harris, Fitch, and Uhler all gave attention to this group of insects, and their studies together run back to 1820, they naturally could not be expected to recognize all that might have occurred, even in their respective localities. However, absence of records, especially in the case of such good collectors and acute observers, is in some degree presumptive evidence of non-occurrence in the case of a species so abundant as this, and if we assume an introduction of the species at some period closely prior to its first notice we must recognize a rapid spread over the whole country, as it is stated by Van Duzee in 1914 to 'occupy North America from Ontario and Connecticut to Alaska and California and South to Mississippi.' There is in the records concerning the species in this country no sequence of dates which furnishes us any basis for tracing any dispersal from some center of introduction, as records for such widely separated points as Illinois, Iowa, Ontario, Washington, D. C., California, and Tennessee appear all within five years of its first notice."*

Whatever the time and mode of its appearance in this country it is now one of the species that must be reckoned with in our agriculture and therefore a knowledge of its habits and life-history is needed. While some information on these points has been published the data are very meager and as stated in the paper previously mentioned, "The life history of the species has never been given in detail, though brief statements concerning the nymphal period appear in some cases. Leonardi barely mentions 'larva and nimfe' in connection with reference to the

*Since the above was written I have seen in looking over the Harris collection in the Boston Society of Natural History, a specimen of this species probably collected between 1840-50 and which would indicate the occurrence of the species at a much earlier date than shown by published records. However, the absence of records would indicate lack of abundance for the species.

species as a pest of cereals." I gave a short description of the nymphal stage but was unable to give the stages in detail or to determine as to the number of generations annually. While we still lack some of these details it has been possible this season to trace the development through from egg to adult and for the latitude of Maine at least the facts secured will furnish a much better basis for measures of control that have previously been available.

Crops Affected.

This species has quite a wide range of foodplants and consequently is liable to become a pest to a number of crops but in Maine its most important attacks I believe will be found to be directed upon the meadow grasses and oats.

Its presence in meadows is almost universal and while it is not so abundant here as some of the other species probably because of its migration to adjacent grain fields, it must be counted as a constant drain especially in meadows of several years standing. On account of its numerous broods rapid development of the nymphs and ready flight of the adults it is more rapidly distributed into new fields than most of our meadow species and consequently rotation may not be as effective in its control.

As a pest of oats it is one of the most conspicuous in its attack of any of the oat-feeding species although its work is very easily mistaken for that of plantlice or thrips. In Maine the attack on oats begins almost as soon as the plants are above ground when their succulent character is evidently a distinct attraction to the leafhopper and at this time adults may be swept in numbers from oat fields especially if they are adjacent to old meadows. It is possible that there are two broods here before the ripening of the crop but we have complete evidence of the development of one generation both by rearing on plants in cages and by field observation. This generation begins with egg depositions in the oat leaves in early July as detailed under life history and matures by the middle of August or before the ripening of the grain and is then ready for flight to fields of more succulent character than the oat stubble.

The appearance of the infested oat plants is fairly characteristic though as suggested above may resemble attacks of thrips or plantlice.

The most evident effect is the production of numerous spots on the leaves these spots being at first whitish then turning to yellow then to brown and later to black often a black or brown center being surrounded by a reddish or yellow border and very much resembling a fungus affected spot. This resemblance is so great that the presence of fungi has often been suspected and efforts made to determine it. In fact I have often been in doubt whether certain spots could be charged to insect attack or fungus and have hesitated to assign the injury to the insect. The presence of eggs in the infested leaves or the demonstration of punctures where the hoppers have been sucking the plant cells however will leave no question as to the cause. Prof. Morse of this station who has made careful studies of these injuries states that he has been unable to find fungi present in connection with the spots except late in the season and when they may very probably have followed as a sequence of the hopper punctures.

The egg punctures and the feeding punctures are different enough so that they usually may be distinguished with the aid of a lens and the egg punctures do not as a rule show the coloring which follows the punctures and sucking of sap where the insects feed. The eggs are deposited mainly in the upper part of the leaf sheath or close to the stem on the basal part of the leaf blade. They are forced in beneath the epidermis usually close to the under epidermis but not through it and thus lie in the layer of cells between the two epidermal surfaces of the leaf. The result is a transparent spot that is usually quite apparent especially if the leaf is held up to the light.

The feeding puncture is by itself a very minute affair scarcely to be detected except by magnification but the sucking of the cell contents produces a deadened spot which as already described changes color with time until it becomes brown or black. The change in color may be assisted by the injection of some secretion in the process of feeding which has a poisonous effect on the plant tissues as is the case in some of the other species of leafhoppers notably the species producing curly leaf

of the beet (*Eutettix tenella*) which has been described in detail by Dr. E. D. Ball. It seems the more likely since there appears to be a decided tendency for the affected leaves to change color and wither at the tips as well as around the punctured spots and these effects differ from those of the plant lice which are also suctorial and so far as withdrawing sap must act very much like the hoppers.

Inasmuch as the leafhoppers, plantlice and thrips are so commonly found associated even on the same plants a comparison of the effect on the leaves may be useful. It may not be possible in every instance to say positively simply from the looks of injured leaves without the finding of the insect concerned just which one has been at work but from examination of a great many leaves I believe that it is generally possible. Thrips injury on the leaves show as minute dots or lines usually running parallel with the leaf veins and remaining white. If in the larval stage they may be seen with a strong lens running actively about on the leaf surface and some individuals will be found beneath the leaf sheath where their presence is likely to be indicated by whitened spots. In the head they produce the blasted flowerets so well described by Dr. Hewitt. (Jour. Economic Entomology Vol. 7, p. 211.)

The plantlice which may be of two species as determined by Dr. Patch (*Macrosiphum granaria* and *Aphis avenae*) cluster mainly at or near the tips of the leaves or at the base of the flowerets and travel much less freely than either the thrips or the leafhoppers. Their results show in withering of the leaf or floweret but without, for some time at least any particular discoloration. The young leafhoppers on hatching usually crawl out upon the leaf in which the eggs were deposited but they drop or jump readily if disturbed and unless the leaves are examined with great care not to agitate them there is little chance of finding them in connection with the spots which they have produced. Moreover they seem to wander freely so that numerous punctures will be found on leaves where there is no other sign than the punctures that they have been present. The character of the leaf spots made by their punctures may be indicated by the photograph reproduced in Fig. 12, but unfortu-

rately the color features can not be shown without a color plate. There is sufficient agreement in habit between the thrips and the leafhoppers so that this distinction may be of little economic necessity but infestation from plantlice must be from other sources and in any case there is an advantage in knowing the exact nature of the insect that may be most prevalent in any community or field so that such preventive measures as may be possible may be applied intelligently.

Another means of identification for the leafhoppers where the living insects cannot be found or where no eggs are evident is found in the presence of the moulted skins of the nymphs. These retain the form and show the characters of the nymphs and as they remain attached to the leaves, often for some time after the emergence of the insect, they are a good proof of the presence of leafhoppers. Their absence however cannot be considered as proof of no hoppers as they are not firmly attached to the leaves and are easily dislodged by shaking or the brushing of leaves together in the wind. The series of photographs of these moulted skins, Fig. 11, will assist in the identification and they may be readily examined with the aid of a low power lens.

Life History.

There is considerable irregularity in the life history of this species and it is difficult to state any definite periods for the development of the stages especially if any large area of country is considered. In Maine adults are to be found in plenty in late June and early July and there is a pretty well marked brood occurring in July, which is found abundantly in oat fields, and it is this brood which has been the basis for our most definite records as to length of instars and rate of growth. Adults were found with developed eggs July 10th, and from these eggs were dissected for comparison with eggs deposited in the plants, and eggs from adults confined on oat plants in the insectary were laid about the 10th and began hatching on the 23rd.

The eggs were laid in the leaf sheath and at base of leaf blade and a little tuft of white strands mark the place of puncture. The egg lies head end to the opening and in a short time the eyes become quite conspicuous. The eggs often lie in close

rows of four to six in a row but also very commonly as scattered single eggs. The arrangement on leaf sheath and blade are shown in the figure and for the cases observed there was about an equal distribution between leaf sheath and blade. The eggs do not pass entirely through the leaf but lie between the epidermal layers so that if the leaf sheath is stripped off the eggs come with it even in very thin parts. A little blister shows on the outside and the eyes appear as minute red dots. The eggs are set obliquely to the vascular bundles and minute reticulations of the inner epidermis may be seen covering the egg if examined with a lens. On the blade they are thrust through from the upper surface but lie closer to the under epidermis. Thirty-seven eggs were counted within the length of an inch on one stem of oat.

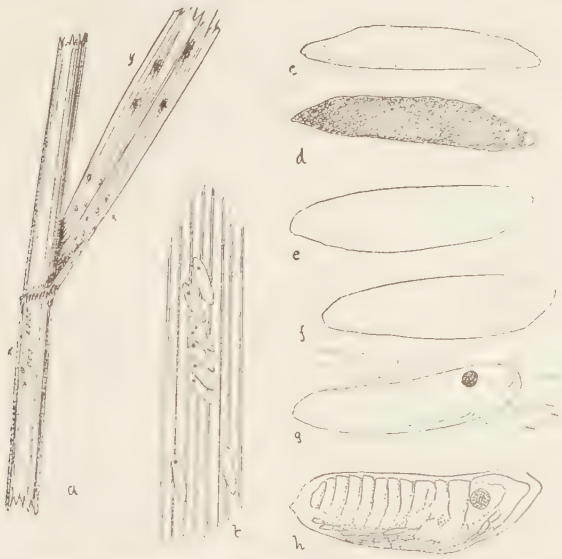

Fig. 1. *Cicadula sexnotata*. Eggs. *a*, Oat stem and blade showing points of egg deposition *x* and feeding punctures *y*; *b*, eggs as seen in plant tissue; *c*, egg dissected from female, surface view; *d*, egg dissected from female, sectional view; *e*, freshly laid from oat stem; *f*, eye spot appearing; *g*, eye distinct egg in network of plant cells; *h*, embryo with segments developed; (Original).

On emergence from the egg the nymph is light yellow with red eyes but they soon become tinged with dusky and will be noticed as minute blackish specks on the leaf surface. The

egg punctures after the eggs hatch are still visible but less conspicuous and will be detected as minute white or transparent spots and in many cases the remnants of the egg shell can be seen as proof of the presence of the insects. The incubation period for this time of year is about seven days as shown by different sets of eggs one set laid Aug. 4th hatching Aug. 11th. In these the eyes became conspicuous on the fourth day after deposition.

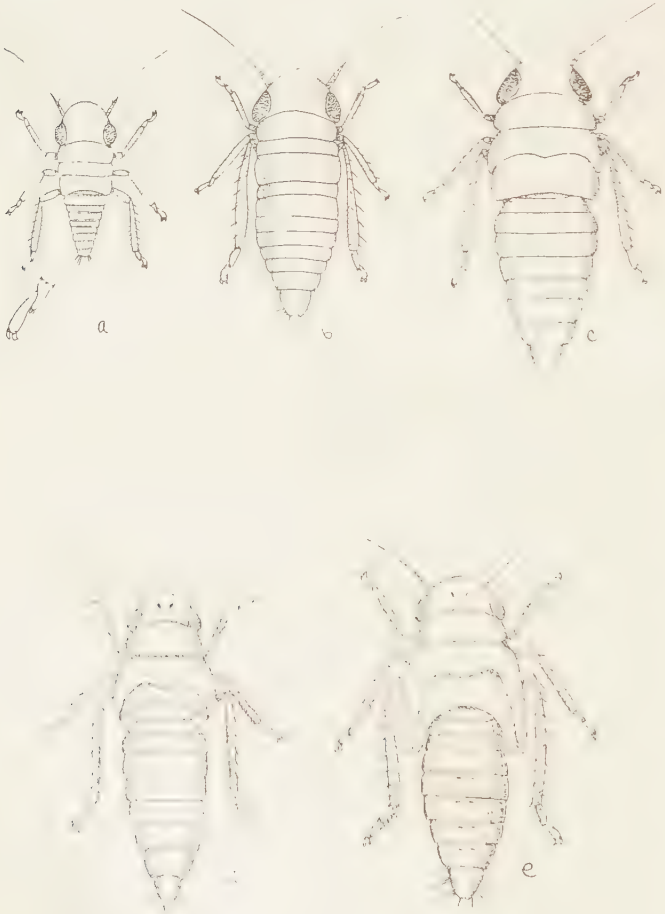

Fig. 2. *Cicadula sexnotata*. *a*, 1st; *b*, 2nd; *c*, 3rd; *d*, 4th; *e*, 5th instars of nymph. *f*, tarsus of *a* much enlarged. a, b, c, drawn to larger scale than d, e. (Original).

Moulting occurred in three days from hatching the 26th of July for the eggs hatching July 23rd, a second moult occurred four days later July 30, the third moult on Aug. 3rd, and the fourth moult on Aug. 6th, with final moult and appearance of adults on Aug. 11th, or twenty days from hatching, about twenty-seven days from egg deposition. Allowing a probable week or ten days in adult stage before egg deposition begins would give us five to six weeks as the period of the summer brood and at this rate it would be an easy matter to have three or four generations in a season for the latitude of central Maine

The nymphs when first hatched cling pretty closely to the leaf but may crawl around and especially toward the tip of the leaf and the leaf becomes spotted with their punctures. These at first appear white but later change to red and then to black and the leaf in severe attacks will shrivel and turn yellow, in bad cases the whole leaf turning yellow and shriveling. The appearance is shown in the photograph reproduced in Fig. 12.

Description of Early Stages.

The eggs as dissected from adults July 10th and as examined from leaves are slender with a length of .8 mm and a width of .16 mm narrowing at either end, the head end wider and with a clear space while the remainder of the egg contains minute globules as seen by transmitted light. Fig. 1 d. The surface of the egg is smooth the chorion with no apparent markings.

1st instar: The nymphs on hatching are .6 mm to .7 mm long and at end of the instar have reached a length of slightly over one millimeter. The head is large and rounded in front much produced, half its length, before the eyes. Prothorax about half the length of the head, mesothorax short, transverse, meta-thorax about the length of the prothorax the sides slightly extended backward and the hind border slightly concave. The hind tibiae bear six spines on the hind border and there are six or eight spines on the end of the abdomen and a comb of three or four short curved spines on the end of the sub-anal plate.

The antennae reach to base of the abdomen and bear on the third segment the usual bristle.

The color is slightly dusky and the moulted skins of this instar have a smoky appearance.

2nd instar: Quite similar to the first but with the head less produced and with fairly distinct transverse bars of dusky color. The hind tibiae have six spines and the terminal segment of abdomen ten or twelve bristles and first tarsal segment of hind legs has two platella.

The color is yellow and the dark markings become quite pronounced toward the time for moulting and the cast skins of this instar show very distinct transverse bands. Length 1.2 mm.

3rd instar: In this instar there is a distinct black mark on the margin between the vertex and front at middle and next the eye and traces of dusky markings on the frontal arcs and across the abdominal segments two to seven. The vertex is distinctly shorter than in the preceding instars and the beginning of the wing pads is distinctly indicated on the mesothorax by expansions of the lateral border but on the meta-thorax they are scarcely indicated. Length, 2 mm.

4th instar: The color markings are as in the preceding instar. Head shorter, the wing pads more distinctly developed, those of the meso-thorax extending back half way on the meta-thorax and those of the meta-thorax reaching the hind border of the first abdominal segment. Length 2.5 mm.

5th instar: The head is but slightly less produced than in the preceding stage and about as in the adult and the black markings are clearly marked. On the abdomen pairs of black transverse spots are distinctly evident on segments four to eight. The spines of hind tibiæ number about eight. The wing pads of the mesothorax are much longer reaching to base of fourth abdominal segment, those of the meta-thorax also longer but reaching only as far as the mesothoracic pads on the base of the abdomen. Length 3 mm.

In all instars there is a nearly uniform number of the tibial and terminal abdominal spines though there seems to be a general increase in number, those of the tibiae ranging from six or seven in the first instar to eight or nine in the last. The beak extends usually to base of the third coxae. The bristle on the third segment of the antennae persists but becomes less and less evident as it does not increase in size in proportion to the other parts.

As nearly as can be determined by the season's observations there seems to be one generation developing in grasslands before July 1st at which time the adults appear in new oat fields. A later generation develops in the oats between July 15th and August 15th and the adults and this generation appear to migrate either to volunteer oats or other cereals or to grassland. A generation develops doubtless between August 15th and October 1st. The autumn generation possibly deposit eggs which hibernate, although this point has not been determined with certainty. The field cages showed few specimens of this species and their exact hibernation is a question for this region.

It will be seen from the habits indicated that the species cannot be controlled upon quite the same basis as some of the other leafhoppers and especially with reference to their at-

tacks upon oats the application of direct treatment would be difficult. Any measure, by rotation or other method, that will reduce the development in grasslands adjacent to oats fields will of course assist in reducing the numbers attacking this crop.

Since the adults appear on the oats while still small it would be possible to run over the oat fields with a hopper dozer, but this would probably need to be raised somewhat on runners in order to give the best results. In autumn the plowing under of stubble land in which volunteer oats may be started and supporting the leafhoppers may be an assistance in reducing the numbers.

Timothy Crown Leafhopper.

Acocephalus albifrons (Linn.)

This species was taken at various points in Maine during the collections of the summer of 1913 but the abundance and economic importance of the species were not appreciated on account of the peculiar habit of the species preventing its collection in the ordinary methods so generally effective for the other species of the group.

During the present season it has been found in great numbers and so many features of interest developed in its habits that it has been studied as carefully as time and conditions would permit.

The most novel feature of its life perhaps consists in its almost subterranean habit, the nymphs, and the adults also in very large part, living beneath the surface litter of the sod and in many cases being found under the earth especially in cavities around the timothy crowns. This habit came to light in connection with a careful digging over of the soil enclosed under one of the cages placed for the determination of the hibernating places of grass feeding species of leafhoppers. One hundred and thirteen individuals, nymphs and adults of both sexes, were counted under a single cage eighteen inches square and examination of surrounding space in the same field and other old meadows showed this abundance to be very general.

Another feature of interest is the apparent restriction of the species to timothy meadows and so far as all observations

show a quite close restriction to this one kind of grass. So far no specimens have been found in places where timothy is not present and while it cannot be asserted that it cannot live on other grasses we may confidently assume that this is its principal food plant.

The nymphs and the adult males have a light clay color blending well with the soil and very different from the females, also very different from nymphs of such species as feed above.

The life history of the species appears to follow closely the other species having a single brood each year and which are adapted to rapid development of nymphs during the early summer.

Fig. 3. *Acoccphalus albifrons* L. *a*, nymph of last instar; *b*, male; *c*, female. All enlarged, natural size shown in length lines at left of each figure. (Original).

At the time of the first observations on the species both nymph and adults were to be found and there is every reason to believe that the adults were the maturing individuals of the seasons brood of nymphs and that they were developed from nymphs that had hatched from hibernating eggs. That the eggs are deposited and hibernate in the fields is shown by the finding of the nymphs and adults in the cages placed in early spring. There were no dead adults or remnants of their bodies as might have been expected if the adults hibernated and deposited eggs in spring. The early nymphal stages were not observed but the stages observed in June and early July were well

advanced in development and were probably for the most part in the final instar as adults began appearing in early July.

The nymphs of the final instar are 2.3 mm in length for the male and nearly white with black markings. There is a broad central patch on the vertex narrowing behind with lateral bands which merge with the central patch behind the middle, a cross band connecting them in front of center, eyes black center, light border; pronotum white with narrow black stripes at side and a central spot on front and rear margin divided by white line, meso- and meta-thorax with broad lateral stripes covering most of wing pads and a central stripe divided by a broader white line, two spots on meta-thorax lateral broad stripe on abdomen to last segment central double stripe terminating on the base of the last segment.

The female nymphs are similar to the males but larger about four millimeters long head and thorax 1 3-4 abdomen 2 3-4 mm width 1 1-4 mm. The black markings on the dorsum are very distinct the central black spot on vertex narrower and a small marginal spot half way from tip to eye, central double stripe broken into black quadrate spots on abdomen, lateral stripe also of quadrate spots on abdomen interrupted on wing pads. Beneath black on margin of front. Hind legs lined with black, tarsal tips black.

Adults were secured emerging from confined nymphs on July 21. The females were darker below than the males and emerged from nymphs that were lighter and larger than the male nymphs. One female taken in the cage July 21 was very light gray but the females are generally dark gray to blackish and assume this color soon after emergence. The dark gray or blackish color is mottled finely with white and toward the end of the elytra these mottlings merge into transparent spots and even become transparent white with black spots and lineations.

Emergence in some of the confined individuals occurred on grass blades above ground and in one case the nymph crawled up to a height of three inches above the ground to attach itself to the grass stem. In one attached an inch and a fourth from the earth the fore legs were attached and the hind legs stretched out backward to the tip of the abdomen. In many cases however and probably as a quite common, if not the usual plan for the species now, the exuviae are found on the ground.

In the moulted nymphal skin the dorsal slit through which the adult emerges is so closely drawn together that it is hardly possible to distinguish any break. The hind legs are extended backward, the hind tibiae meeting behind the tip of the abdomen and the hind tarsi resting side by side. The nymphal skins retain their appearance of the nymphs so completely that they furnish every character necessary for identification.

Adults become abundant by the middle of July and from this time forward the nymphs decrease in number rapidly till by the last of July practically all are in the adult stage. The first matings were observed July 30th, the mating individuals resting on grass leaf about one inch from the ground.

But little mating was observed however and it appears that this is deferred to late in the season and while oviposition was not observed it is pretty safe to conclude that egg deposition is carried on slowly during late summer and early autumn and that the eggs remain undeveloped till the following spring and hatch, probably in May or early June, reaching maturity in July.

Control.

It is evident from the habits of this species that it must be treated in a different manner than most of the common leafhoppers of timothy meadows as the fact that it is so completely protected under the grass or even down in the sod makes it difficult to reach by the hopper dozer method. It is also doubtful whether it will be as much affected by burning over as some of the other species although this will depend upon whether the eggs are deposited so as to be exposed above ground or well protected down in the crowns of the plants. Exact determination of place of egg deposition is desirable in this connection.

There can be little question that rotation is a most effective treatment for the species. There is apparently very little migration of the adults from one field to another and even if some movement should occur, plowing in late fall or early spring would serve to very effectually destroy all eggs. A very good evidence of the effectiveness of rotation is found in the fact that the species has been found only in old timothy meadows, the worst cases in fields that had been in grass for many years and that none at all have been observed in fields of only two or three years in grass.

Of the natural enemies found with the species it would appear that the spiders must be the most effective as they are abundant in the fields and they work down among the bases of the grass plants where they have excellent opportunities to feed upon the hoppers.

Acocephalus striatus Linn.

This is one of the species collected in abundance in the summer of 1913 and which it was deemed desirable to follow further for the purpose of getting life-history details that might be a better basis for the determining of measures for control. It was taken in all parts of the state where collections were made and may be considered as of general distribution but it is found in greatest numbers in meadows and pastures and especially in timothy meadows. There appear to be no references to it as an economic species in American works and so far as I know no studies in this country upon its life-history or habits from an economic standpoint. It has been noted in collections from Canada and the New England states for many years and while a well known European species there is little reason to look upon it as a recent introduction.

Fig. 4. *Acocephalus striatus.* *a*, young nymph 1st instar (?); *b*, intermediate nymph; *c*, nymph of last instar. All figures enlarged, natural size shown in length lines at left of each figure. (Original).

It has been found associated with a number of different plants but the nymphs have been taken especially in grassland usually where there is an abundance of timothy and if there is any very close restriction in food plant this grass is probably its preference.

The observations confirm pretty positively the occurrence of but one generation each year the adults maturing in July and living on into the fall with pretty certainly fall oviposition and hibernation in the egg stage. Nymphs were found in good numbers in our cages placed in early spring which proves hibernation in the fields and the absence of any signs of adults either dead or alive shows pretty conclusively that eggs are laid and adults die in fall. Furthermore the development of eggs had reached such a stage in August that it would indicate fall oviposition.

The first nymph observed was taken at Eliot on June 26th apparently in the first instar and at Orono young nymphs (1st instar) were taken July 2nd. One in 2nd instar on July 1st and these would indicate hatching in late June probably as early as June 20th for all the southern part of the state.

The nymphal stages are passed rapidly as the period between the first noticed nymphs and earlier adults is but about four weeks. The first adult observed in the fields at Orono was taken July 1st, a male, and these became fairly plenty by the middle of the month. The females mature a little later, the first taken July 18th, than the males but no mating was seen until after August 8th. The latest nymph observed was one in last instar on Aug. 8th. The greatest abundance of nymphs occurred during the first week in July when the different stages were all pretty well represented in field collections. By July 28th adults of both sexes were abundant and scarcely any nymphs were to be found.

Description of Nymphs.

The youngest nymphs found were two millimeters long and were probably first instar individuals but partially grown. They are green in color with outline of the adults but quite different in color, the grass green color of the upper side is flecked with black dots. Below fainter green.

The second stage nymph observed (2nd instar) is three and one-half millimeters long of very much the same shape as the earlier form but with a slight indication of the formation of wing pads in enlargement of the lateral parts of meso- and meta-thorax.

The color is grass green tinged in places with yellowish and above flecked with black dots which are most numerous on the posterior part of the meta-thorax. Beneath there are dots on the face very scant on

the clypeus and there are scattered dots on the legs mostly on the upper side.

The face is distinctly roughened in places, the hind tibiae have two rows of strong spines, nine or ten in each row, and the hind tarsi have two platella on first joint, three ventral.

The last instar (3rd) is six millimeters long and longer in proportion than the earlier stages the sides distinctly parallel the wing pads of meso- and meta-thorax well developed extending back on to the base of the abdomen to the 2nd segment.

The color is green a little paler than for the earlier stages and the flecks of dark dots are less evident, being smaller in proportion than for the younger nymphs.

The nymphs are very easily distinguished from the larvae of other leafhoppers by the flattened bodies and the rather sharp margin of the head with the parallel sided form of the abdomen. They have more the general appearance of the nymphs of *Gypona* than for the strict jassid genera.

The figures will assist in recognizing the species in the early stages.

The habits of this species differ somewhat from the typical leafhoppers as they seem adapted to living on the ground or close to the surface though by no means so specialized in this regard as the *Acocephalus albifrons*. The larvae creep around on the ground very commonly but will be found also on the stems of the plants or even well up on grass blades but they do not jump so readily as some species and while taken in fair numbers in the sweep net the numbers caught in this way are not as good an index of the abundance of the species as for many other kinds. Their color is well adapted to protect them in the grass and they may very easily escape notice unless one is looking especially for them. The adults also run around very commonly on the ground but climb up on the stems of plants readily and are taken in abundance in sweeping. At first light green, they change to shades of gray or dull straw color fitting in well with the color of dead leaves and stems. In both larval and adult stages therefore they are admirably fitted to escape attention of the casual observer and it is not at all strange that they have not been associated with the falling off in the hay crop that is noticed in old meadows.

Their attack is made on stems and leaves but for the young especially it is probable that they work at the base of the stems or even down on the crown which offers a juicy point of attack.

Since this species has been found in every timothy field of over two years standing and in many cases has been found in great abundance it must be credited with a considerable share in the drain caused by leafhoppers. Its most serious attack must naturally occur during the growth of the larvae from the middle of June to the middle of July, which coincides with the time when the hay crop should be making its most rapid growth.

Suggestions for Control.

Evidently the most important feature in control for this species is the rotation of crops and, since the species seems to migrate less readily than some of the other forms, this should be effective on fields that are not allowed to remain in grass for more than three or four years. Since the species hibernates in the field and in all probability is represented in the egg stage in stems or leaves of grass, burning where this is practicable should be effective. The insects do not jump quite as readily as some other forms and might not be collected as completely by the hopper dozer as with some other forms but a proportion could be secured in this manner and, if the process is used for the leafhoppers in general, it would assist in reducing their numbers.

Chlorotettix unicolor.

This species was noted as quite abundant, especially in low ground and on the rank grasses in the southern part of the state. It is one of the largest of the leafhoppers and when occurring in abundance must occasion considerable loss. Its life history has not been traced entirely through the year but the nymphal stages have been observed and a description and figure will assist in further recognition of the species. The nymphs observed were evidently in the final instar and have the length of 8 mm. They are light green in color closely matching the color of the grasses on which they occur. The wing pads are yellowish and extend on to the basal segment of the abdomen. The head is somewhat fuller than in the adult stage, and the abdomen tapers from near the base to quite an acute tip. The nymphs occur most abundantly in July and dur-

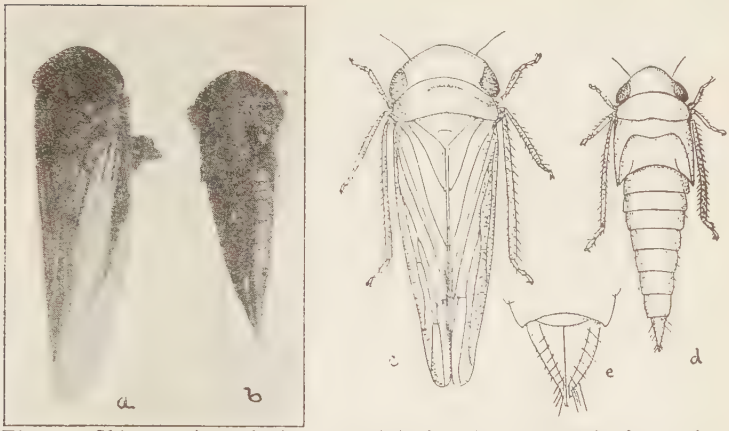

Fig. 5. *Chlorotettix unicolor.* *a*, adult female; *b*, nymph, from photograph; *c*, adult female; *d*, nymph, last instar; *e*, genitatia of male. (Original).

ing July and August adults appear in abundance and in the latter part of the season adults only are observed. It seems probable that a single generation for the year is the rule for the species in Maine but this can not be stated with certainty.

Idiocerus provancheri.

This species recorded as occurring in bogs was collected in July in both nymphal and adult stages. A wider description of the nymphs may be of service in further recognition of the species.

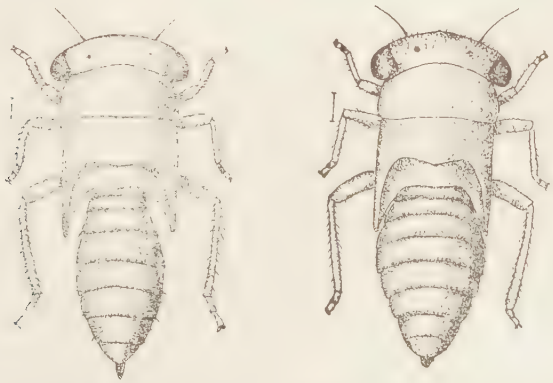

Fig. 6. *Idiocerus provancheri.* *a*, male; *b*, female nymph of last instar. (Original).

The female nymph of the final instar is 4 mm. long and the head 1 1-2 mm.; the abdomen narrower at base but wider than in the male.

The color observed is brown with the vertex yellow and the pronotum yellowish or tinged with yellow; the wing pads brown with the sternum and disc of the venter yellow. There is a pair of round black spots on the vertex in the male and the length is the same as for the female. The general appearance is similar but the abdomen is much more slender and with genital processes much more elongate. The abdomen is much restricted at the base, appearing almost wasp-like and leaving a wide space between its margins and tips of the wing pads. The color in most specimens agreed with that of the females but in one specimen was jet black above and on the base with light yellow on the sternum and disc of the abdomen, otherwise agreeing with the other nymphs. These were collected rather sparingly on July 10th, eight nymphs and twenty adults both were beaten from small bushes in the bog and all the nymphs taken at this time were in the 4 mm. stage. It is quite evident that this is the last instar as no forms intermediate between these and the adults were found at the same time and place. They approach more closely to the nymphs of *maculipennis* than to any other species.

Draeculacephala angulifera Walk.

The nymphs of this species agree in color with those of *D. mollipes* but the head is distinctly shorter, the front angle not sharper than a right angle and the dark greenish stripes of the dorsum are different. A pair of dark lines run from near the tip of the vertex to the base of the terminal segment of the abdomen. These enclose a distinctly light dorsal line and outside of the dark stripes, the upper surface is light green. The frontal arcs are quite distinct and both vertex and front slightly tumid. Length of the specimens noted and figured is 6 mm. The nymphs of this species occur during summer and no indication of more than one brood has been noted.

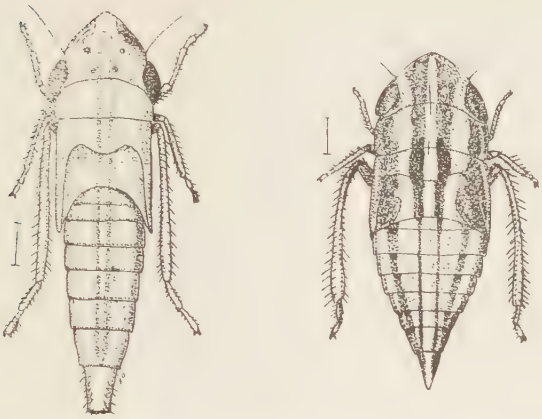

Fig. 7. *a, Draeculacephala angulifera*, last instar nymph; *b, Phlepsius apertus* last instar nymph. (Original).

Phlepsius apertus Van D.

The larva referred to this species is quite broad, flattened and with a rather strongly produced vertex. The color is light clay to whitish and there are two broad stripes on the vertex about equally wide on the prothorax, narrower on the metathorax and extended as narrow lines on the abdomen to the terminal segment. They are lighter than the vertex, black on the meso- and meta-thorax and abdomen. A broad marginal stripe covers the sides of the thorax and the narrower stripe and lateral border extend from base to tip of abdomen. Length 5 mm.

Two specimens of this have been secured, one of them August 8th in timothy meadow and from its characteristics it is referred somewhat doubtfully to the above species, although it was not possible to rear specimens to the adult stage.

Balclutha punctata Thunberg

This species is very widely distributed and was mentioned in a previous Bulletin as one of the common forms. It has been taken especially upon Canadian blue grass and during August was found in all stages and while the life cycle has not been followed in complete detail it would be useful to furnish description and figures of the stages observed.

Fig. 8. *Balclutha punctata.* a, b, c, d, 1st, 2nd, 3rd, 4th instars. (Original).

The first instar is 1 mm. in length and there is no indication of wing pads. The head is produced in front of the eyes; the face is dark and the abdominal segments dusky with the sutures lighter, below red with legs dusky.

The second instar is 1 1-2 to 1 6-10 mm. The general color yellowish to light brown streaked with red; face not dotted; the vertical segment slightly produced with faint dusky patches in a medium row on the ventral side of the abdomen. The head is nearly a semi-circle in front of the eyes. The meso-thorax has distinct angles but is not produced into enlargement of wing pads; meta-thorax with sharp hind border, no pads.

The third instar is 2 mm. or more, light yellowish near transparent color, the sutures below lined with red, the wing pads partly indicated and angles with the meso- and meta-thorax.

The fourth instar is 2 3-4 to 3 mm. in length; color light brown to dusky; the wing pads developed so as to reach on to the first abdominal segment. Those of the meso-thorax do not extend to the tip of the under ones.

The fifth instar is 3 1-2 mm. to 4 mm.; color differing, some specimens being distinctly light green and others brown with red; the face and body above, the legs and ventral surface with dusky patches dotted with fuscous points. The wing pads reach to the 3rd abdominal segment, the front ones extending as far as the hind ones. In the female, two lobes and the ovipositor show distinctly and in the male, plates and genitalia.

Fig. 9. Above timothy meadow at edge of cut swath showing at *a*, height of normal or healthy plants; at *b*, height of aborted or stunted plants with blasted or imperfect heads; *c*, cages in meadow for testing hibernation; *d*, cages on Experiment Station grounds used for rearing leafhoppers and froghoppers. (Original).

Fig. 10. Timothy from same field; *a* normal or healthy, *b*, aborted or stunted stems with blasted heads. (Original).

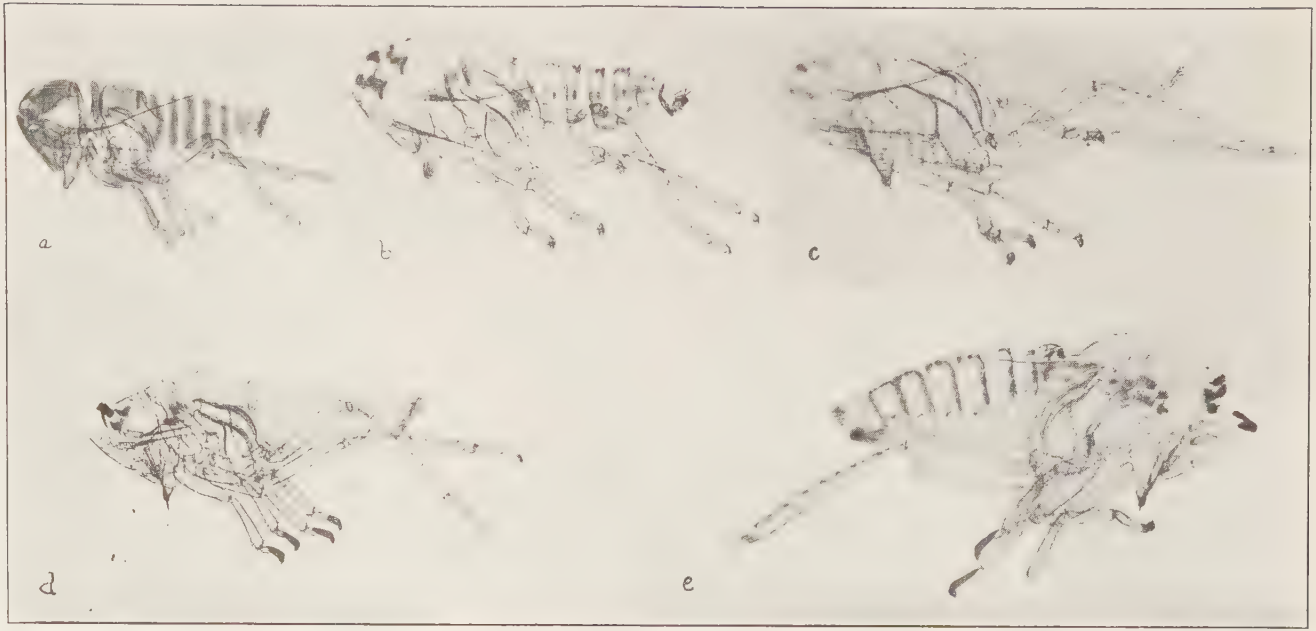

Fig. 11. *Cicadula sexnotata.* Moulted skins *a, b, c, d, e,* 1st, 2nd, 3rd, 4th, 5th, instars, *d,* and *e,* are on smaller scale than the others. (Original).

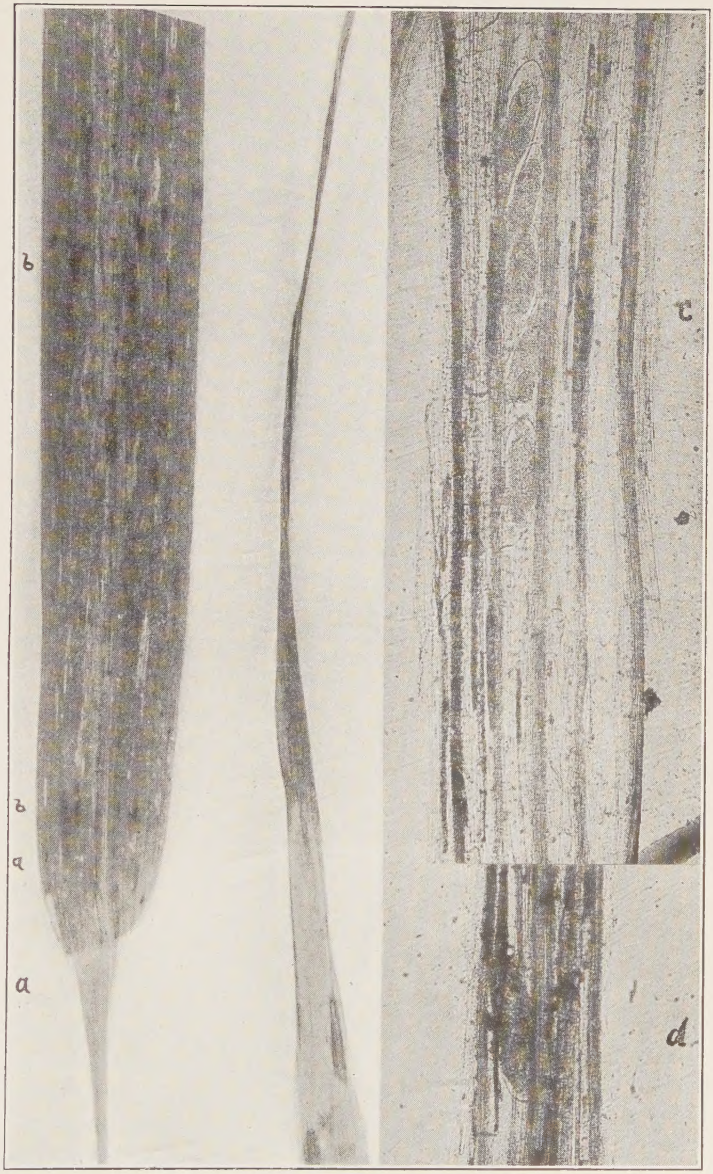

Fig. 12. Eggs and feeding punctures of *Cicadula sexnotata*. Opposite *a*, egg depositions; opposite *b*, feeding punctures; opposite *c*, eggs slightly developed; *d*, embryo well advanced; *e*, withered outer part of blade. *a* and *b*, photographed by reflected light, *c* and *d* photographed by transmitted light to show eggs within leaf. (Original).

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Fig. 13. a, b, males. c, d, females. *Acocephalus albifrons.* e ♂ f ♀ nymph and g to j males, k to n females showing varieties of *Acocephalus striatus.* (Original from photographs by Hammond).

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